→ 3rd SPACE FOR HYDROLOGY WORKSHOP

Surface Water Storage and Runoff:
Modeling, In-Situ data and Remote Sensing

Hydrospace2015 Summary to OSTST

Jérôme Benveniste
ESA-ESRIN
Earth Observation Science, Applications and Future Technologies Dpt

15–17 September 2015 | ESA–ESRIN | Frascati (Rome), Italy

→ 3rd SPACE FOR HYDROLOGY WORKSHOP

Surface Water Storage and Runoff: Modeling, In-Situ data and Remote Sensing

This workshop was organised by ESA and CNES around an organizing committee and in collaboration with the session co-chairs selected from the scientific committee.

The workshop consists of oral and poster presentations selected by the Scientific Committee, and includes a round table discussion.

15–17 September 2015 | ESA–ESRIN | Frascati (Rome), Italy

Workshop Organisation

Jérôme Benveniste, Selma Cherchali, Jean-François Crétaux

ESA-ESRIN, CNES HQ, CNES-LEGOS

- ESA
  - ESRIN: Earth Observation Science, Applications and Future Technologies Dpt

- CNES :
  - Program Directorate, Land and Hydrology Program Manager
  - SWOT French Hydrology PI

Organising Committee

- Jérôme Benveniste, ESA/ESRIN
- Jean-François Cretaux, LEGOS
- Selma Cherchali, CNES
- Paul Bates, University of Bristol
- Peter Bauer-Gottwein, Tech. Univ. of Denmark
- Stephan Bojinski, WMO
- Christophe Brachet, OIEau - IOWater
- Christophe Cudennec, IAHS
- Wolfgang Grabs, Federal Institute of Hydrology, Germany
- Julius Wellens-Mensah, WMO

Scientific Committee (1)

Rodrigo Abarca del Rio	Univ Conception	Chile
Tommaso Abrate	WMO	Switzerland
Abou Amani	Unesco	Kenya
Philippa Berry	Newcastle U.	UK
Charon Birkett	Univ. of Maryland	USA
David Bjerklie	USGS	USA
Aaron Boone	CNRM - GAME	France
François Boy	CNES	France
Phil Callaghan	JPL	USA
Séphane Calmant	IRD / LEGOS	France
Anny Cazenave	LEGOS	France
Agnes Ducharne	Univ Pierre et Marie Curie	France
Michael Durand	Ohio State U.	USA
Roger Fjortoft	CNES	France
Olivier Hagolle	CESBIO	France
Faisal Hossein	Tennessee Tech U.	USA
Andrey Kostianoy	Shirshoff Inst.	Russia
Dennis Lettenmaier	Uni. of Washington	USA
Laurent Longuevergne	CNRS-Géosciences Rennes	France
Ulrich Looser	Global Runoff Data Center	Germany

Scientific Committee (2)

Rodrigo Paiva	Federal University of Rio Grande do Sul, IPH	Brasil
Tamlin Pavelsky	University of North Carolina	USA
Catherine Prigent	Observatoire de Paris	France
Pierre-Alain Roche	ASTEE	France
Ernesto Rodriguez	NASA-JPL	USA
Joecila Santos Silva	Univ. E. Amazonas	Brasil
Frédérique Seyler	IRD/LMTG	France
C.K. Shum	Ohio State University	USA
Daniel Sighomnou	WMO	Cameroon
Larry Smith	UCLA	USA
Bob Su	ITC	NL
Angelica Tarpanelli	IRPI/CNR	Italy
Virendra Mani Tiwari	CSIR-NGRI, Hyderabad	India
Stefano Vignudelli	IBF-CNR-Pisa	Italy
Valery Vuglinskii	SHI Saint-Petersburg	Russia
Eric Wood	Uni. of Princeton	USA
Guoqing Zhang	China Univ, of Geosciences	China

Hydrospace 2015

78 Participants from 25 countries

225 Co-Authors! 76 Abstract Submissions

→ 3rd SPACE FOR HYDROLOGY WORKSHOP | Surface Water Storage and Runoff: Modeling, In-Situ data and Remote Sensing
15–17 September 2015 | ESA–ESRIN | Frascati (Rome), Italy

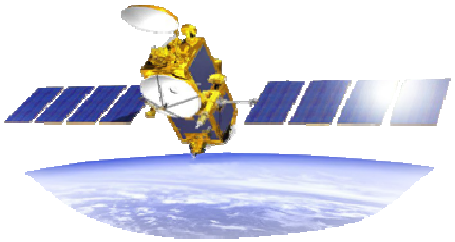
Introduction
The new challenges

- **Climatic and environmental stakes**

" We do not inherit the land from our ancestors, we borrow it from our children"
(Native American proverb)

- What climate shall we have tomorrow?
  - Increases in global sea and air temperatures
  - Widespread melting of snow and ice
  - Rising global sea level

- How to improve our models?
  - What are the observation and accuracy needs for global water and energy cycle research, and for global climate change research? **continental to global scales to augment climate networks.**
- How to predict at a finer scale?
  - What are the accuracy needs for water management, flood prediction, reservoir operation, agriculture and drought assessment? **regional problems and real-time data needs to augment operational networks.**

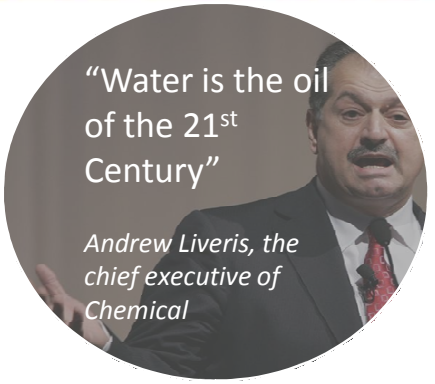


→ To spatialize and to refine scale of perception

  - Observations at high spatial and temporal scales

Introduction
The new challenges

- **Water: a major stake in the 21th century**

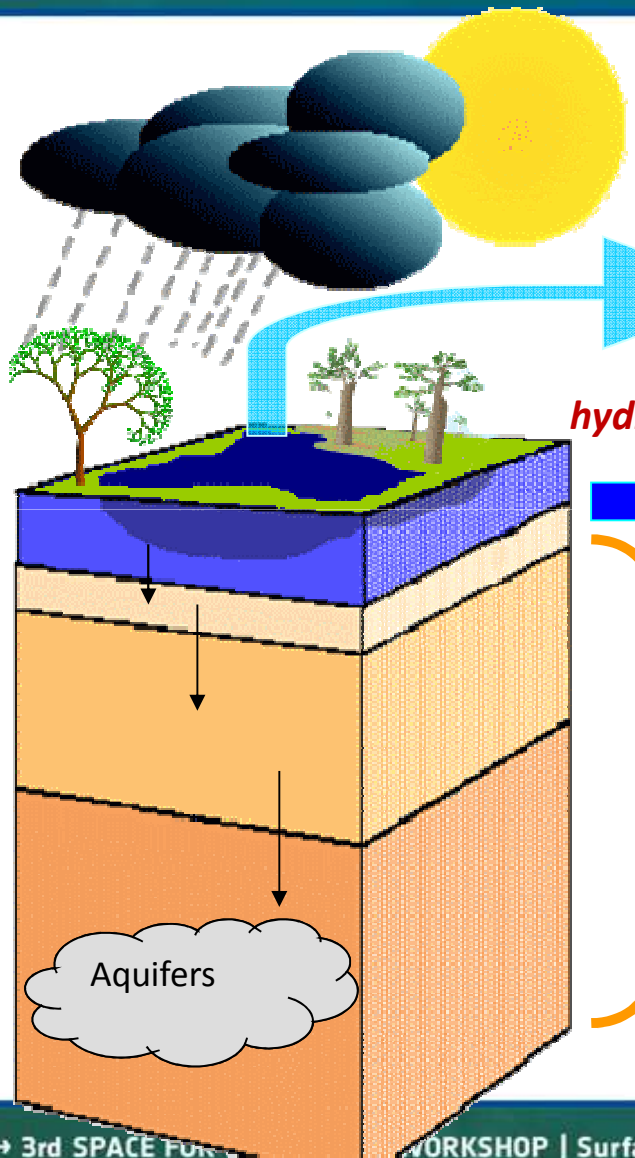


→ **Understanding the processes which govern the production of the water and its distribution in the various compartments of the Earth surface**

- **What type data for tomorrow and which distribution scheme ?**
  - World programs in hydrology and water are looking to space-based observations to provide needed observations **of sufficient accuracy for water resource applications.**

- **What socio - economic benefits?**
  - Consider end-users requirements
  - Benefits of Earth observations applications to decision making
  - Develop services

Space measurements for water cycle



Precipitation, Energy

Vis, NIR, TIR,
Radar Altimetry

Land Surface

Surface Water

hydro network, water storage, Discharge, Evapotranspiration

Soil moisture

Radar and
passive microwave

Ground water

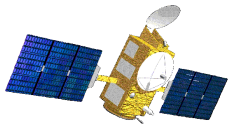
Gravimetry

Space measurements for water cycle

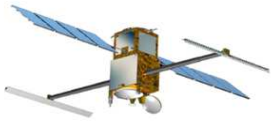
Terrestrial water balance equation

$$\frac{dS_{SM}}{dt} + \frac{dS_{SG}}{dt} + \frac{dS_{SW}}{dt} = P - E - Q$$

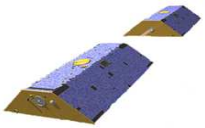
SMOS,
SMAP
TMI, AMSR-E, ASCAT



Jason, **S3**
Saral Altika
SWOT



Jason, **S3**
Saral Altika
SWOT



GRACE
GRACE-2

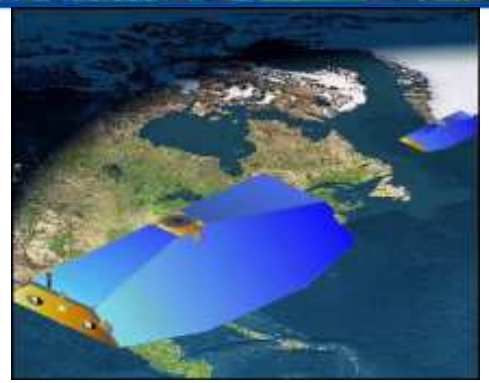
CERES,
AIRS, MODIS
THIRSTY

TRMM,
GPM
Méghatropique
SCLP

Space missions for hydrology

Radar altimetry
Jason 2, 3, CS, Altika-Saral,
Sentinel 3, SWOT

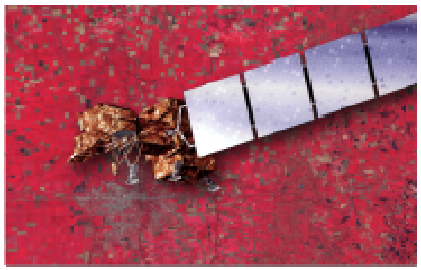
Radar & radiometer
SMOS, SMAP



Satellite Gravimetry
Grace 1, 2

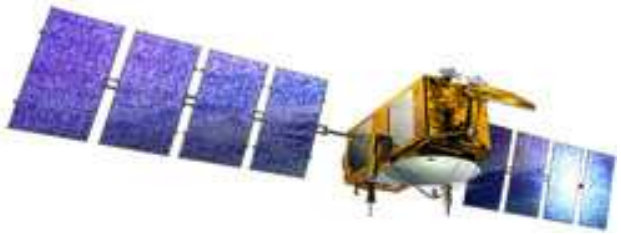
meteorological satellite
GPM/Mégha, IASI, IASI NG

optical satellite
SPOT 5, 6, *7, Landsat 8*
Pléiades 1, 2, Sentinel 2

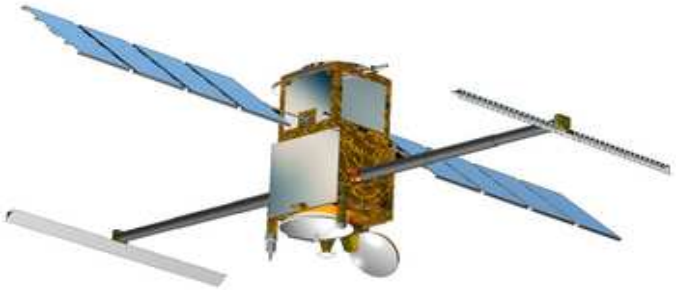


Thermal IR satellite
Landsat, Thirsty/SOIF

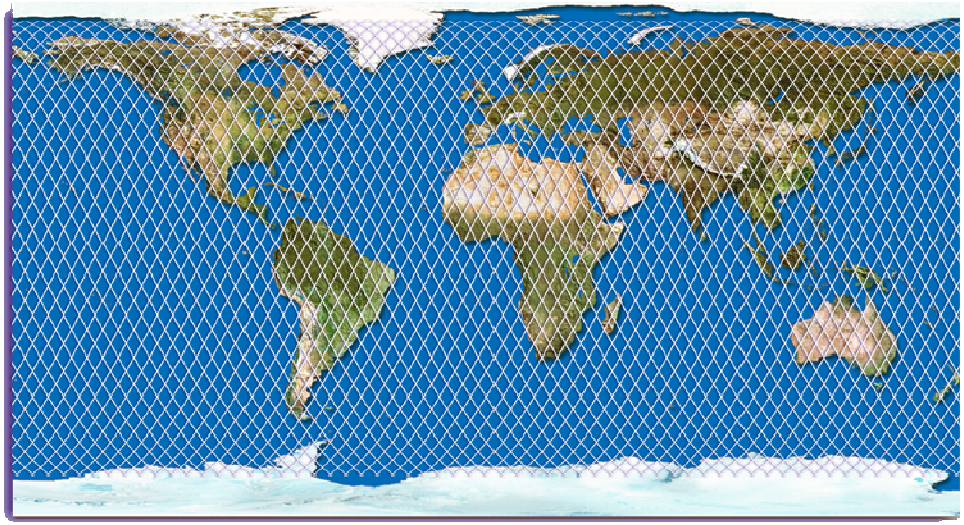
SWOT mission

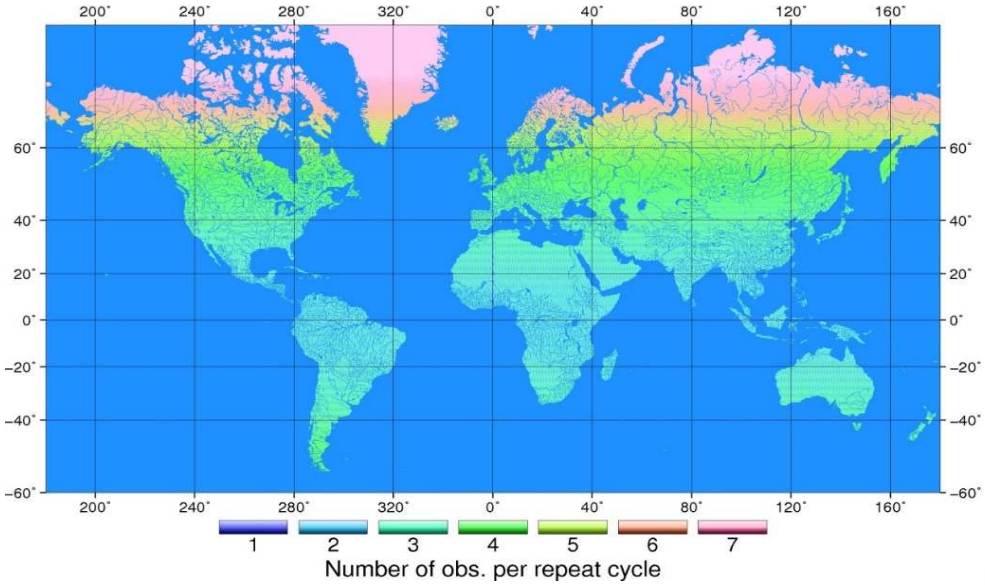


Nadir Altimeter

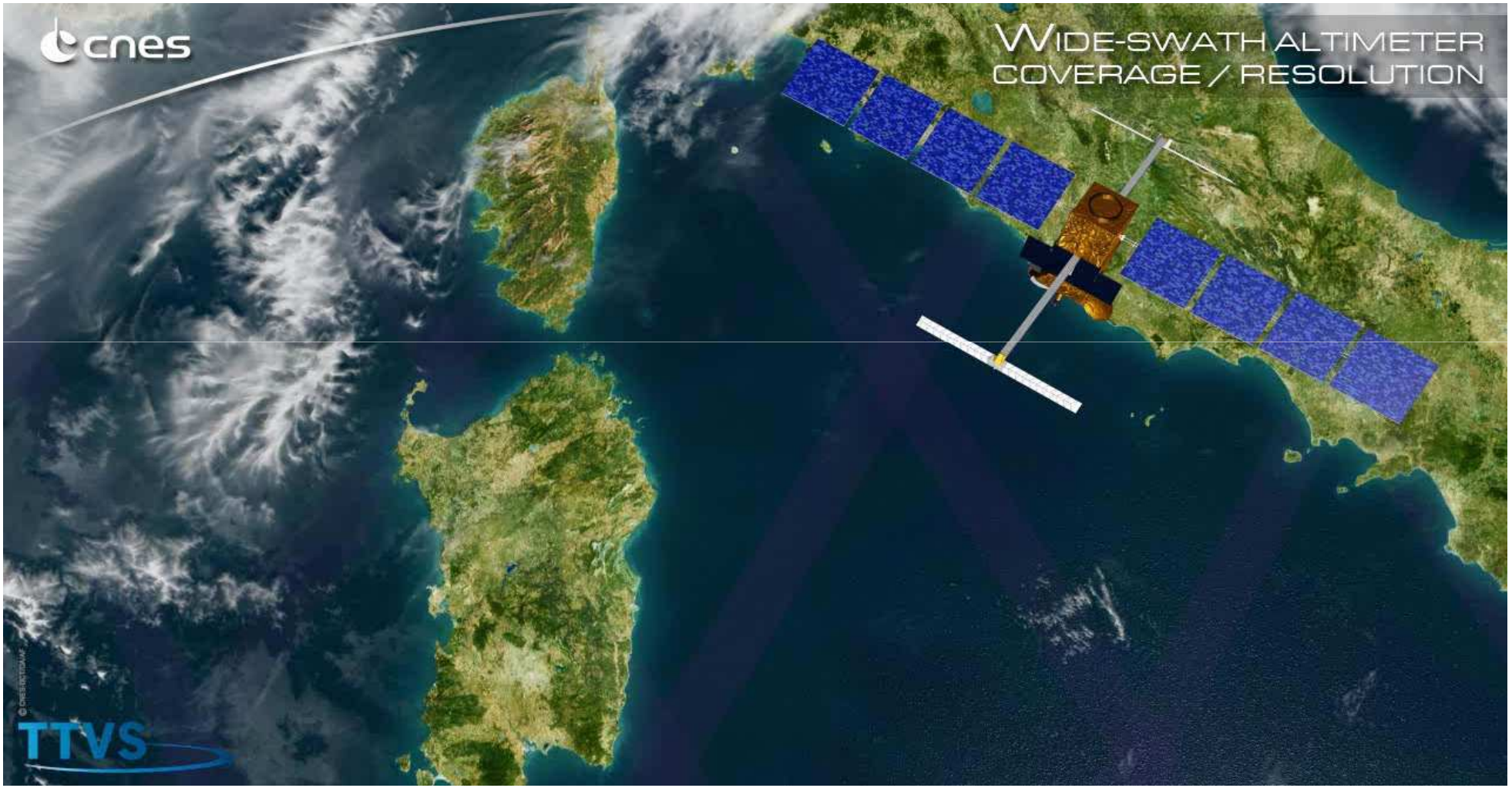


SWATH Altimeter : SWOT





SWOT mission



Objectives of the Workshop

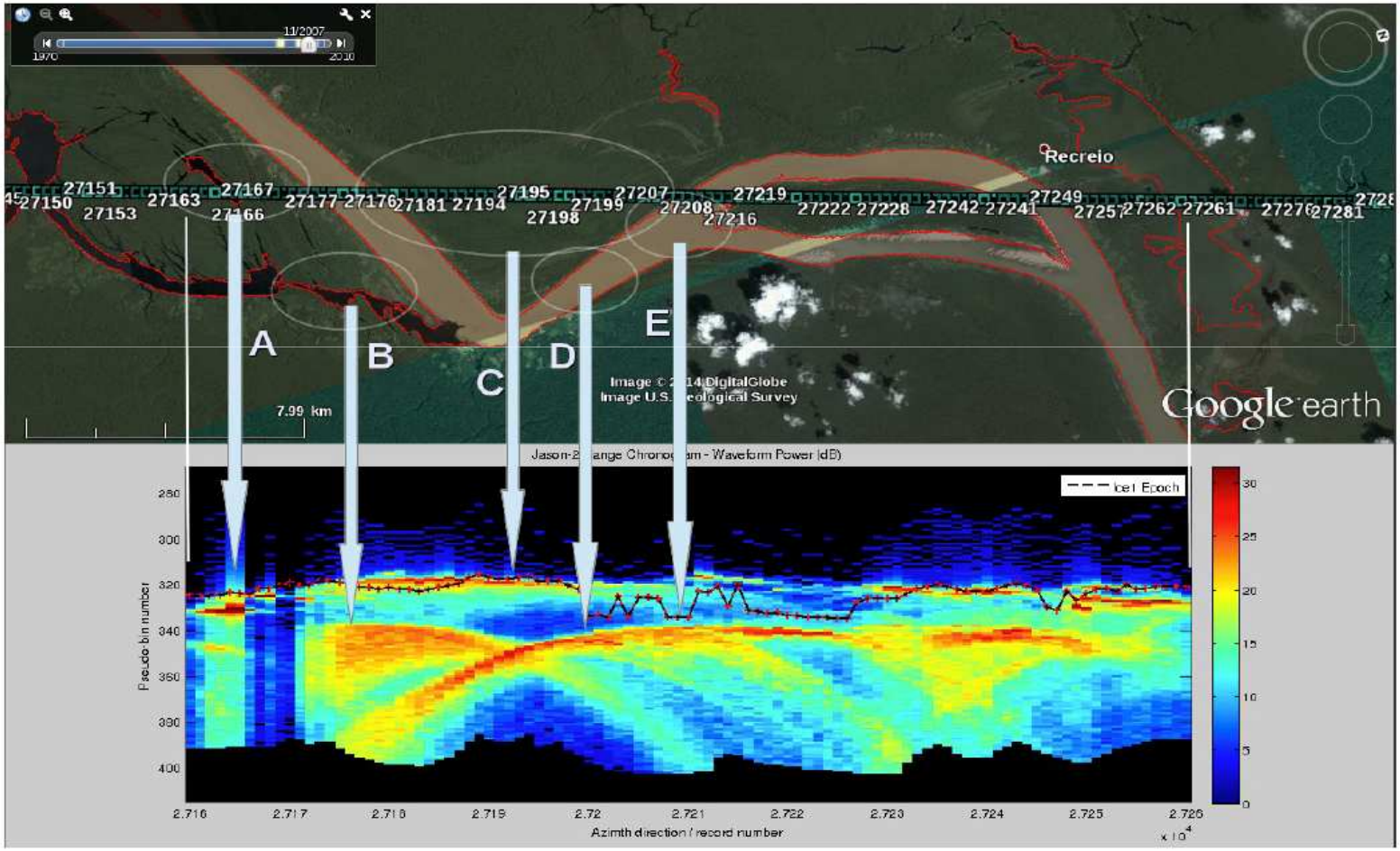
- Prepare for the exploitation of the next generation of altimeters
- Bring together hydrologists and space scientists in order to tackle future challenges in hydrology for water storage and discharge
- Strengthen the collaboration between the 3 communities: modellers, in situ and satellite observations providers
- **Plenty of time slots for discussion!** To **capture the participants' recommendations** for further improvement of space products and encourage new algorithms and products development, (including further functionalities of the toolboxes, training, outreach, etc.).

Round Table and discussion

- Synthesis of the space technologies and physical parameters observation
- The questions of calibration, validation and quality of satellite products for hydrology
- Synthesis of the needs and requirements in term of modelling and assimilation
- Major trends for developments with the new generation of space observations
- Synthesis of the water's actors and development of the interactions between the two communities (Hydrology and Space techniques)
- Access to satellite products and archives by hydrologists

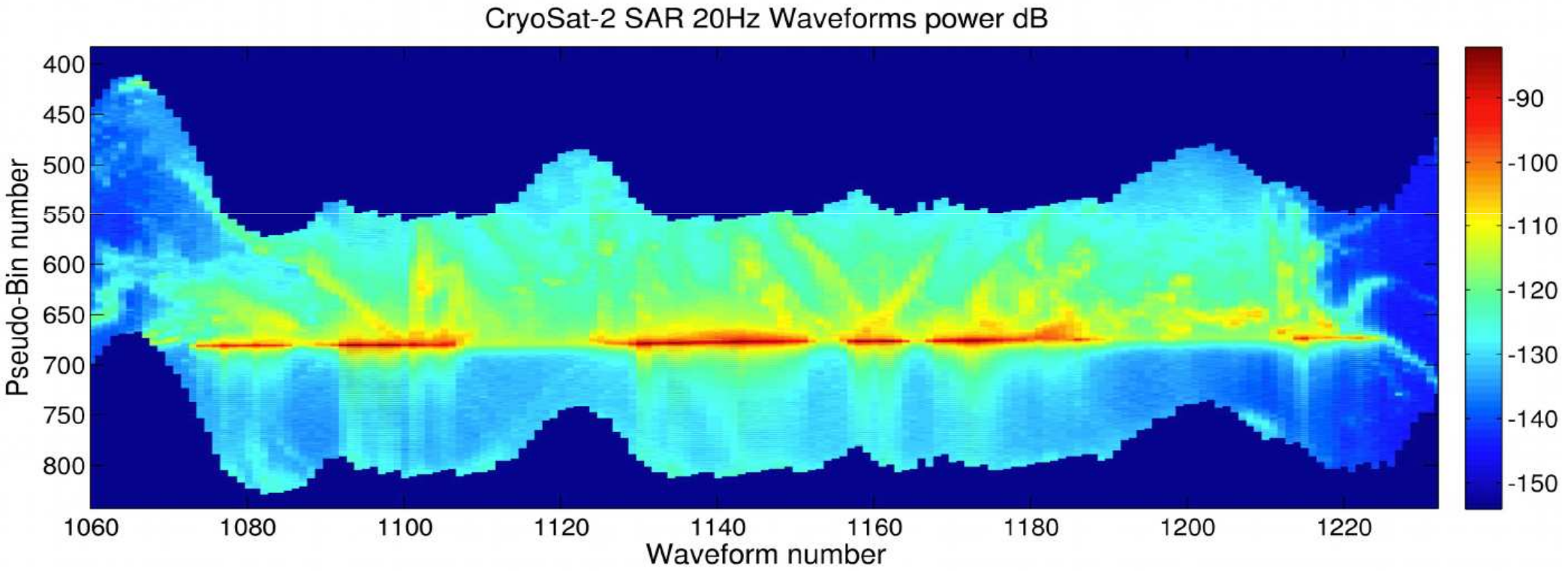
Context

- Contributions of Off-NADIR water areas : LRM case (Jason2) : → hyperboles



Context

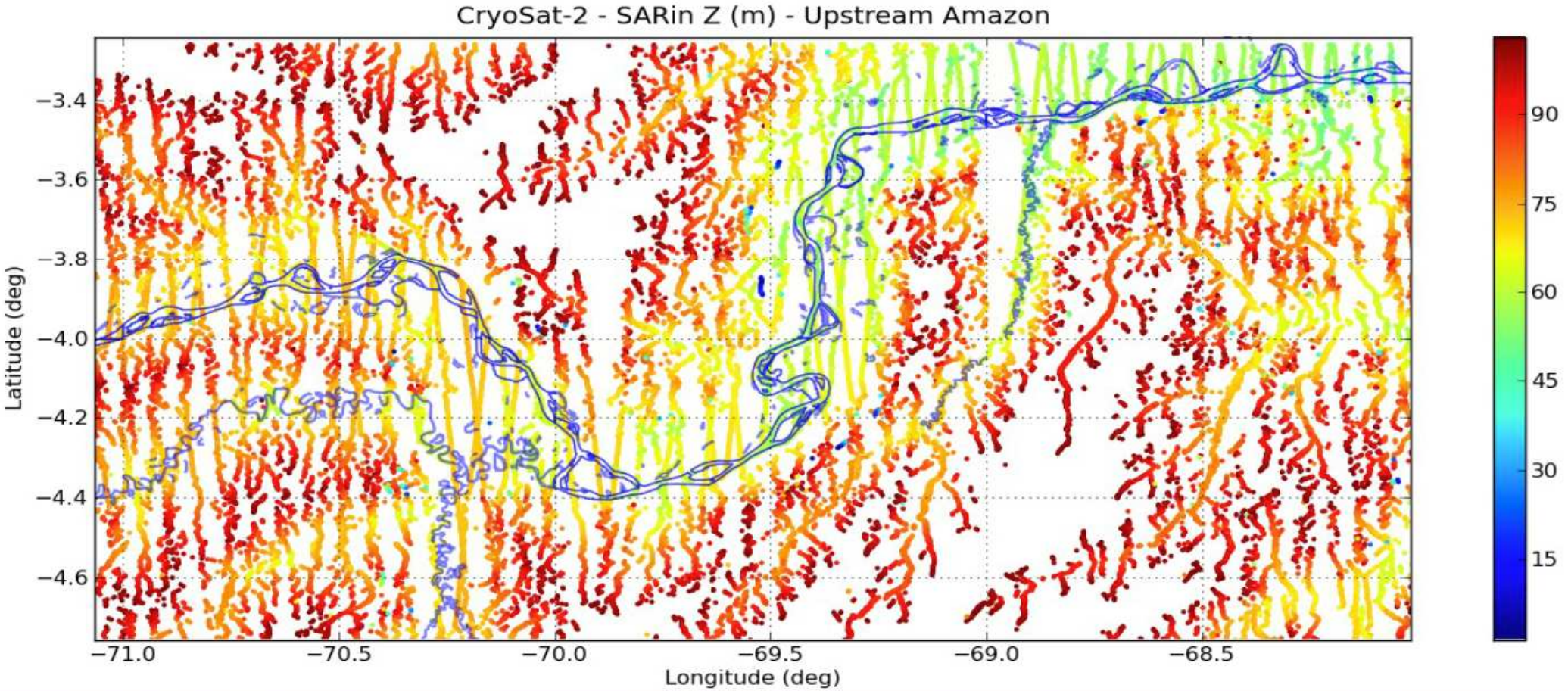
- Cryosat-2 SAR mode showing some **portions of hyperboles** due to **dominant across-track Off-NADIR water areas (Amazon)**



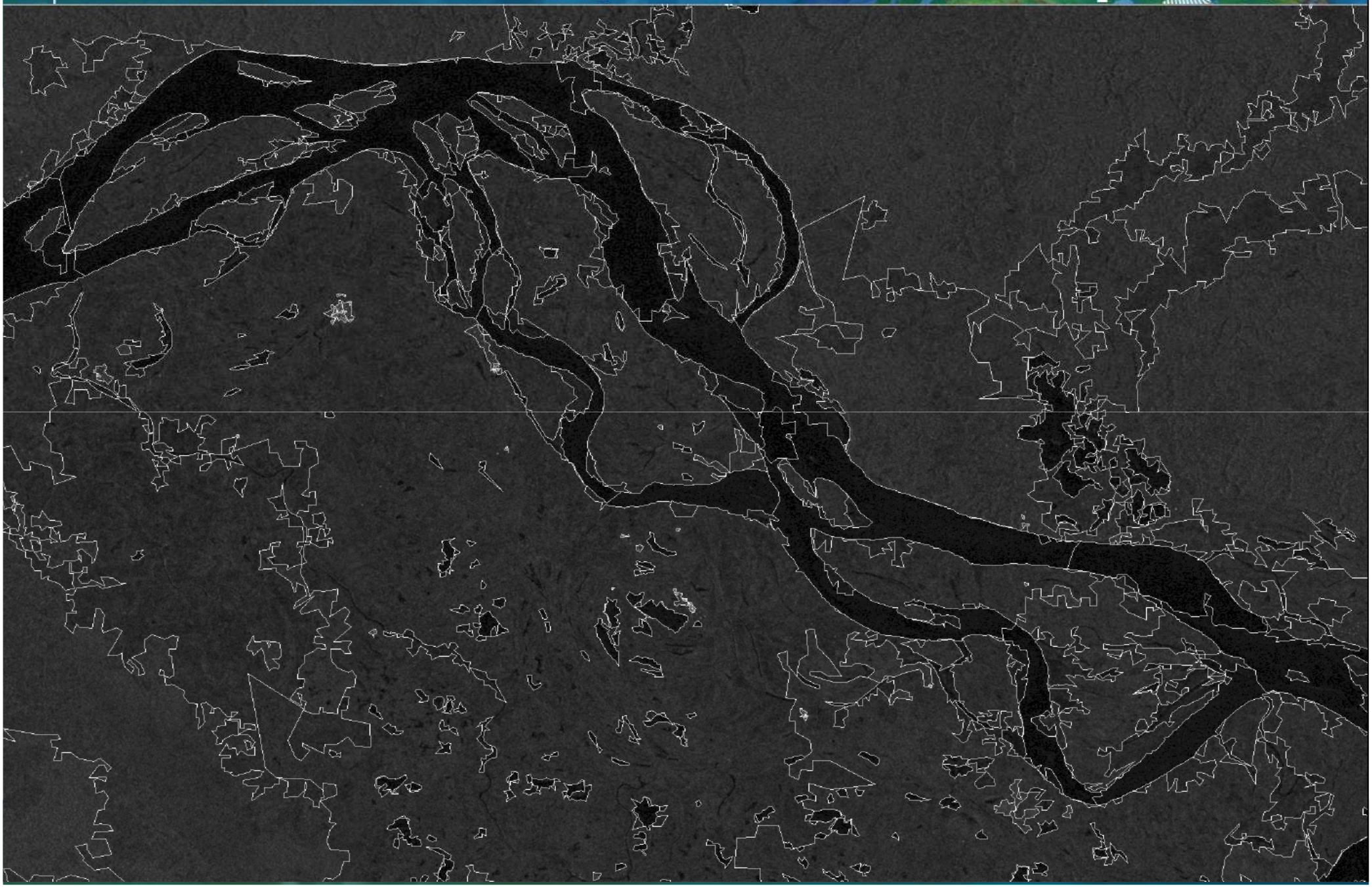
Data from Salvatore Dinardo Nov 2012.

Context

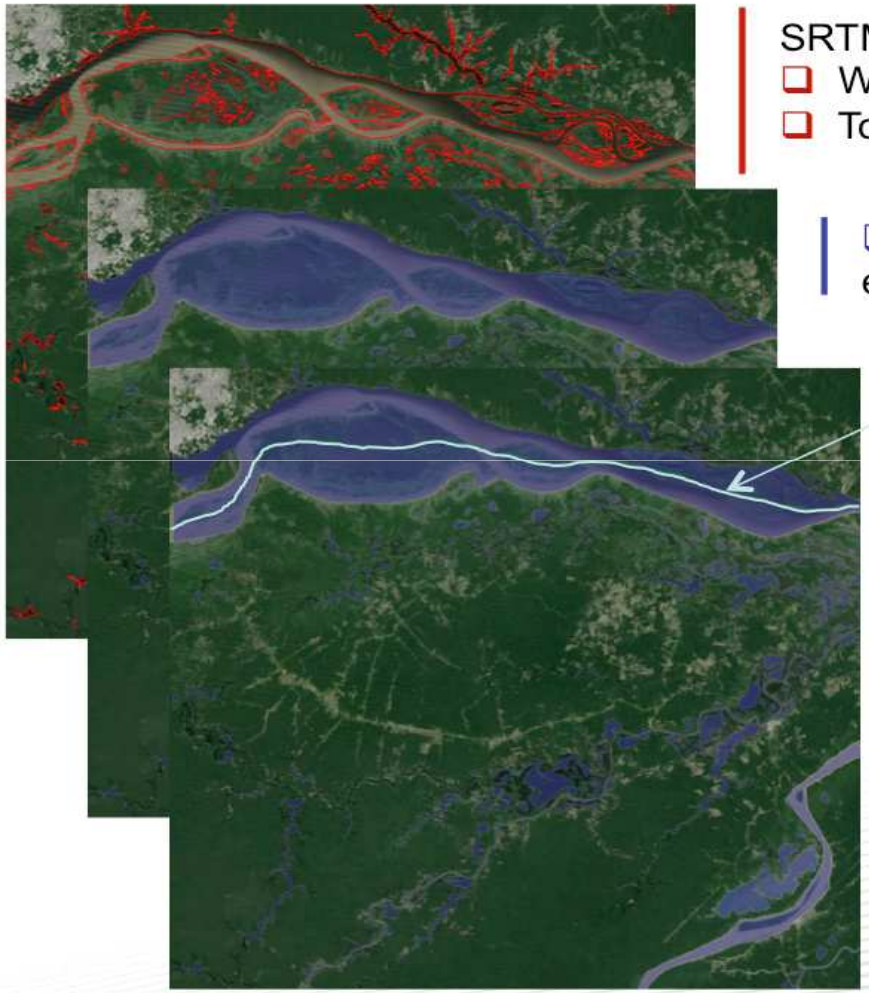
- Cryosat-2 ESA/L2 SARIn showing of Off-NADIR pointing, [Bercher et al., 2013]



Burman River (Sentinel-1, VV polar)



Data editing based on water mask

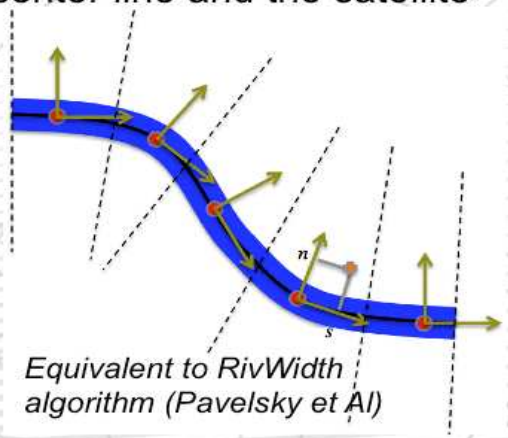


SRTM Water Body Dataset from NASA which provides
- Water surface contours in shapefile format
- Topography at each point of the tile (30 m x 30 m)

- Computation of a land/water mask (raster file) eventually extended for flood event monitoring

- Computation of a 1D curveline passing through the center of the river (res : 15 m)
- At each point of this line, computation of :
  - curvilinear abscissa to a reference point (outfall)
  - river width
  - angle between the center line and the satellite ground track

(central islands can be considered or not)



Equivalent to RivWidth algorithm (Pavelsky et Al)

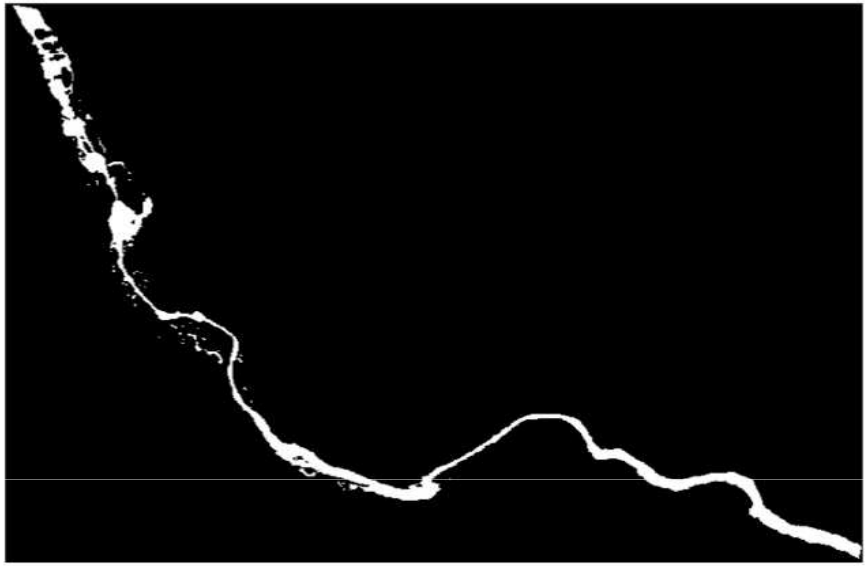
SRTM is a static product but can be replaced by any static/dynamic image - optical or SAR (Sentinel-1)

Newcastle University
School of Civil Engineering & Geosciences

esa

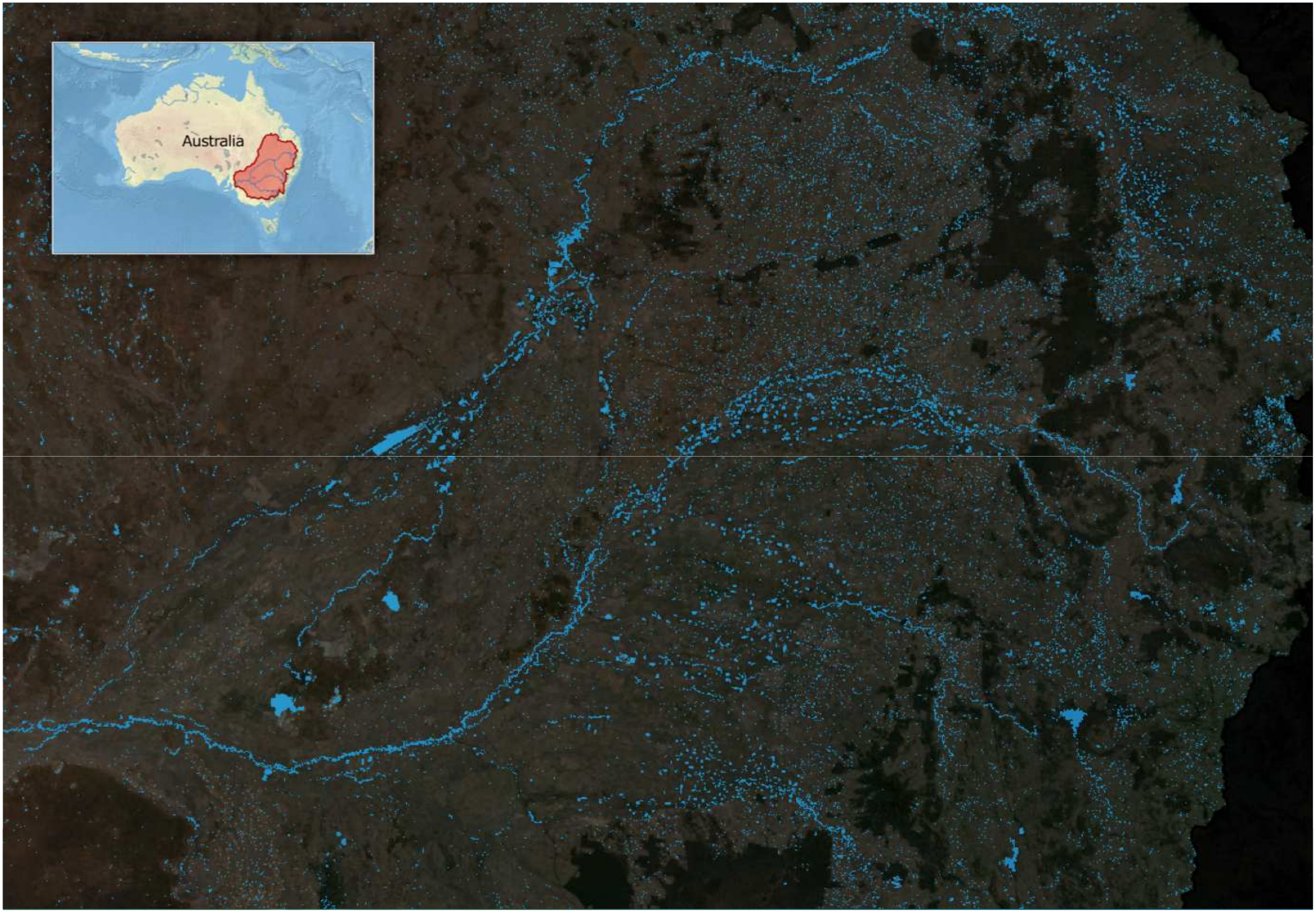
River Mask

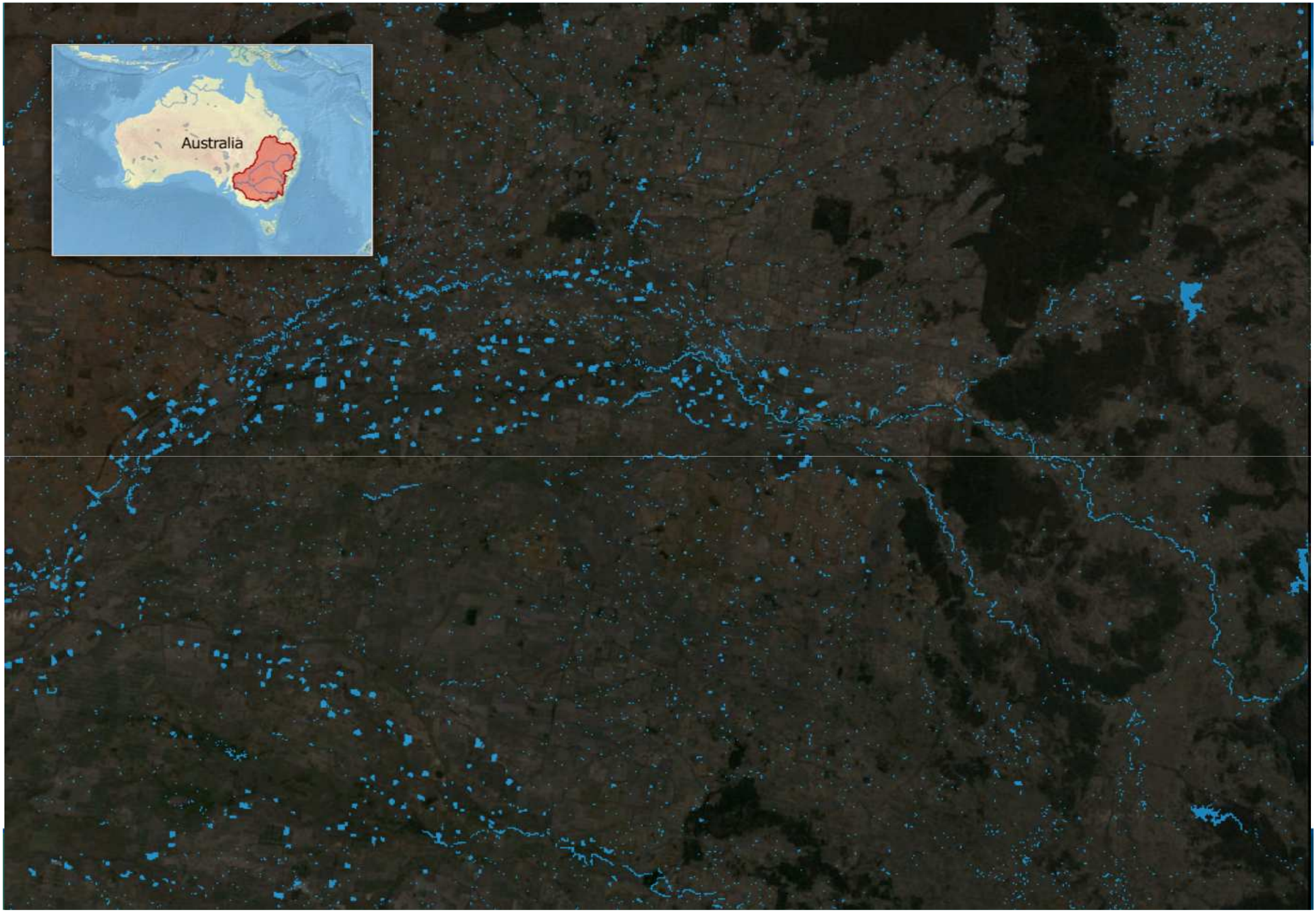
- Three Landsat8 images from November 2014
- Mid-season Flows
- Three images within one week



- Mask Using Landsat 8 data
- Two Stages
  - Approximate river mask
  - Actual water bodies using Landsat images

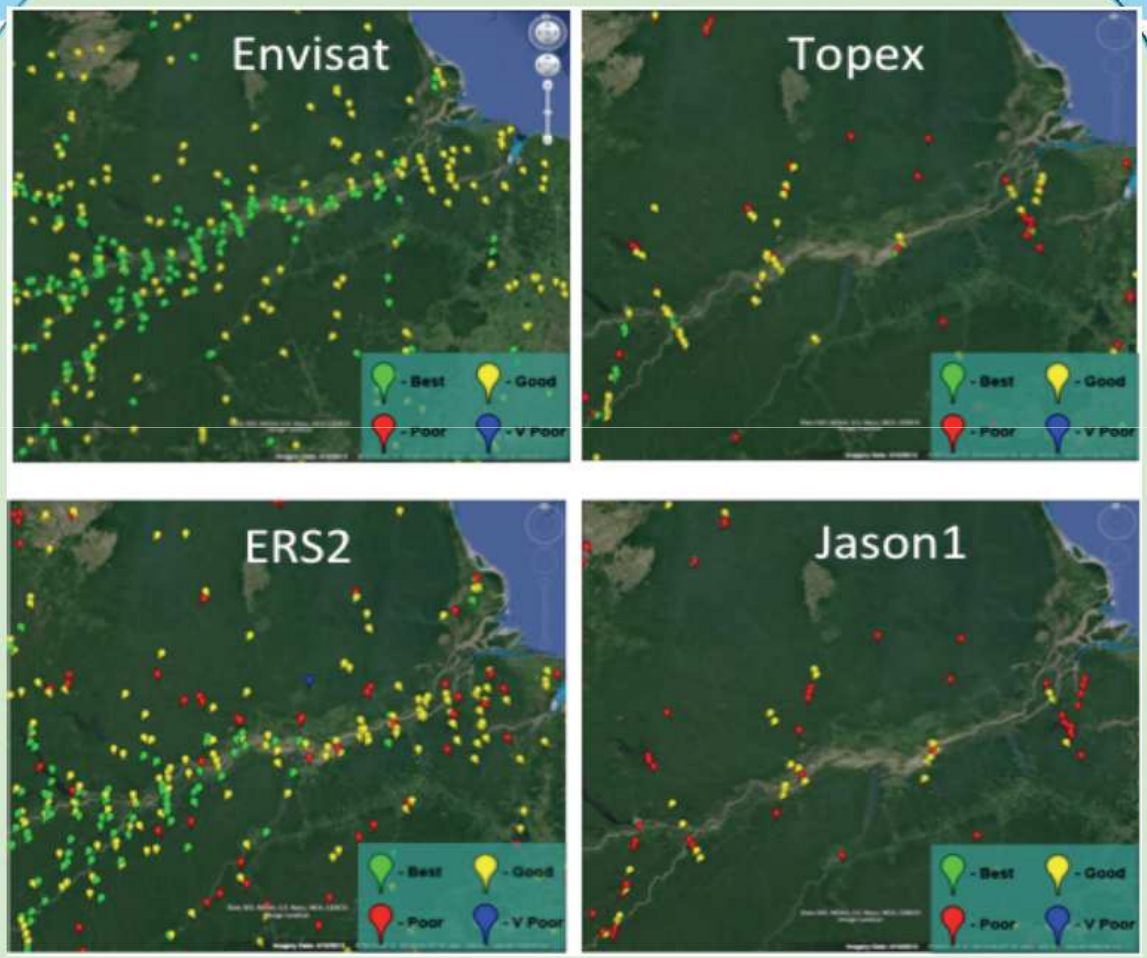

Australia


Australia

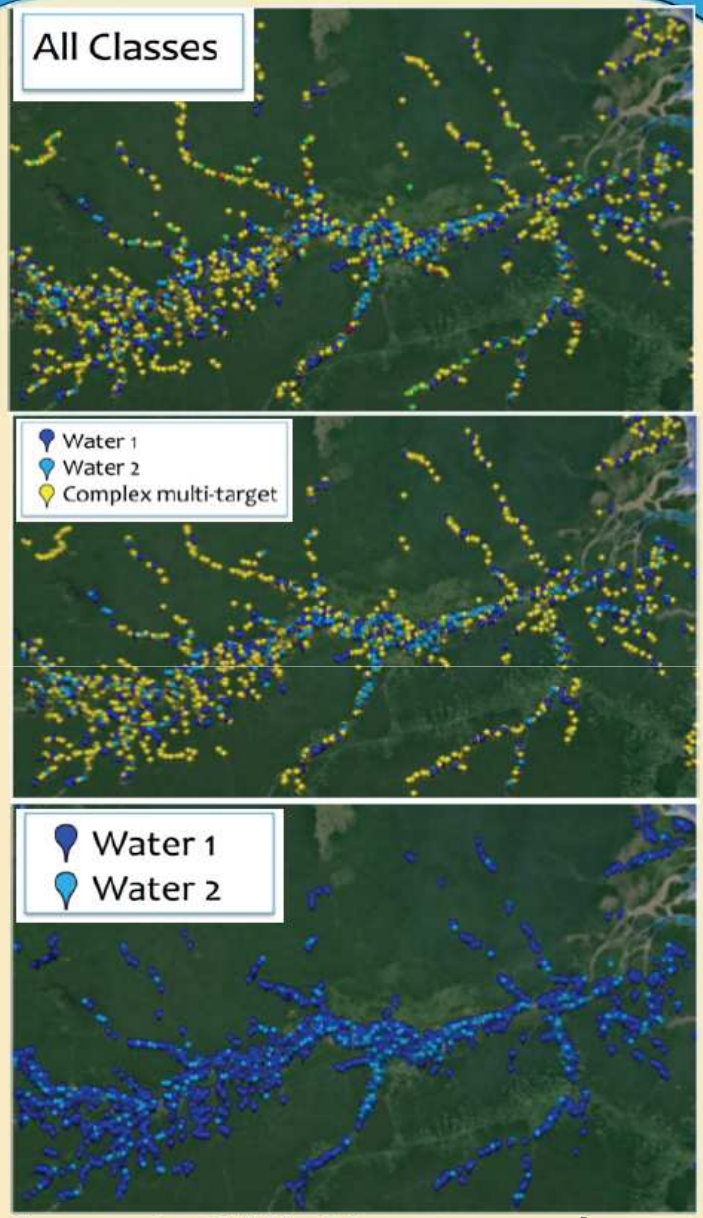

Australia

Newcastle University
School of Civil Engineering & Geosciences

Amazon



Good timeseries from ERS2/Envisat on part of Amazon overflown in SAR mode by Cryosat2



Cryosat2 SAR: Many complex echoes but 'clean' water echoes well distributed

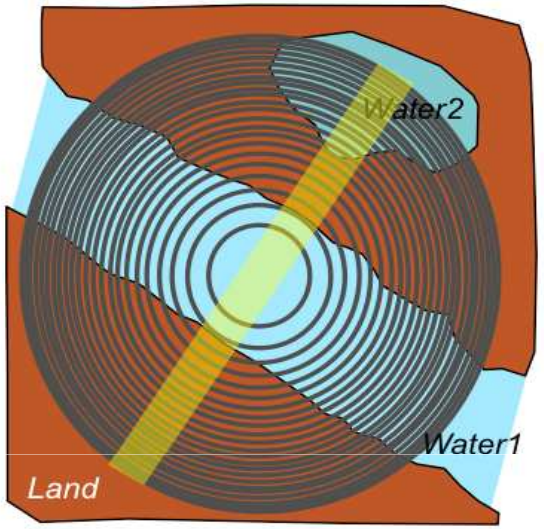
Space observations for hydrology

The observing satellite system can be improved by :

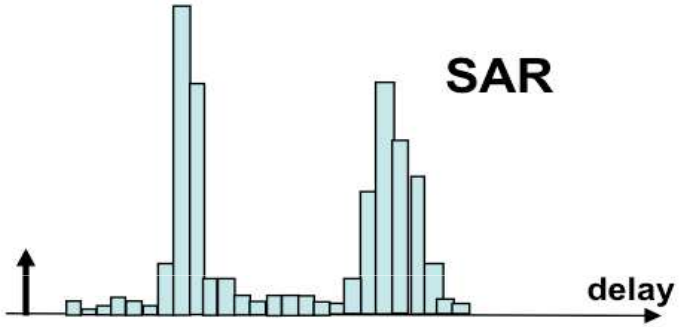
- Enlargement of the constellation (Jason-3, Sentinel-3A, Sentinel-3B, Sentinel-6, …, SWOT)
- Improvement of the performances of each component of the constellation (availability and precision) – Low Resolution Mode Ku, LRM Ka, SAR/DelayDoppler Ku, SAR-Interferometer Ka, … (on board or on ground processing)
- Densification of the measurements from one mission (in space and time)
- Merging of all observations into multi-mission high level products (L3, …)

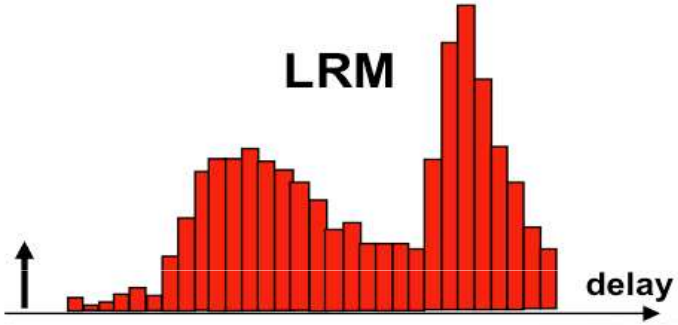
P.Thibaut & al, «Exploitation of the delay/doppler altimeter high performances over inland water domain», HydroSpace Meeting, Rome, Sept 2015

Inland water measurement issues

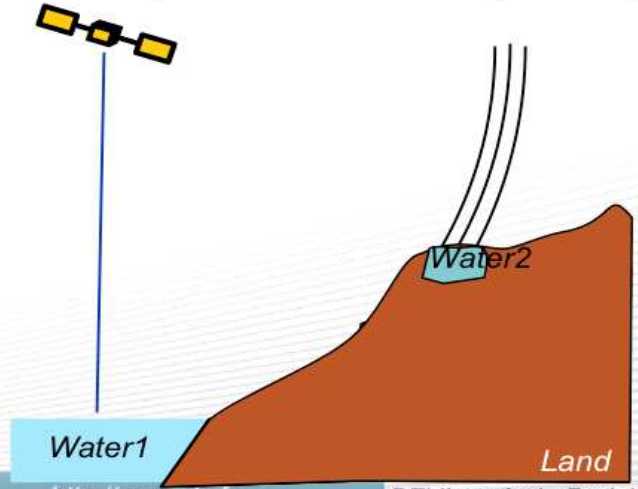


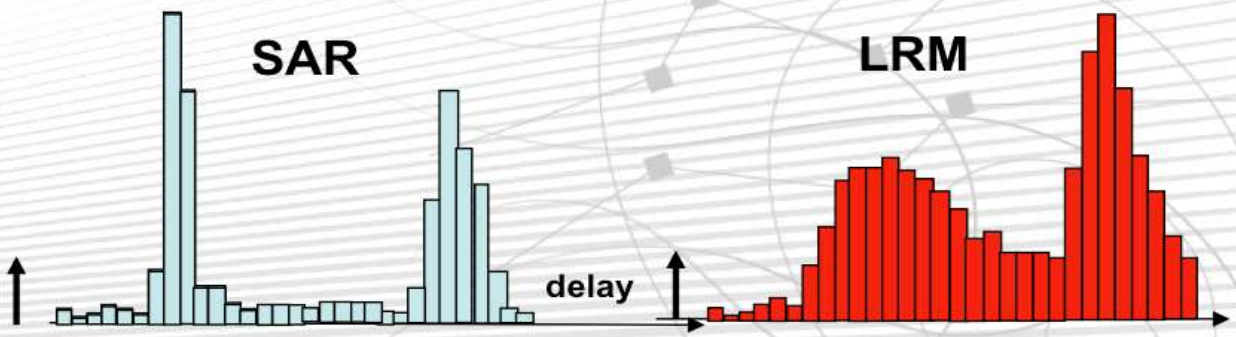
More complex situations can corrupt even the SAR waveforms. We use more sophisticated retracker in this case (multi-peak processing)



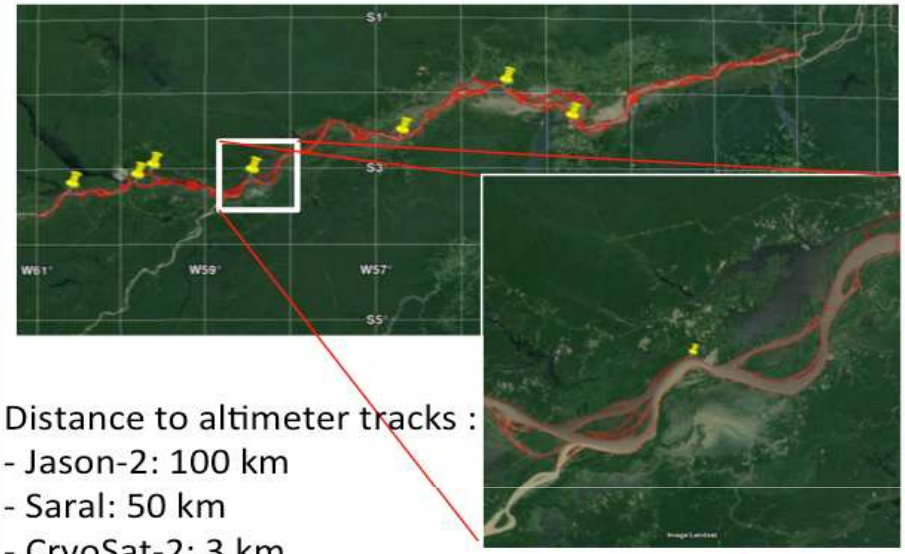


Ambiguity: along an iso-slant-range, many positions of the specular point in location (lat/lon) and heights are undiscriminated





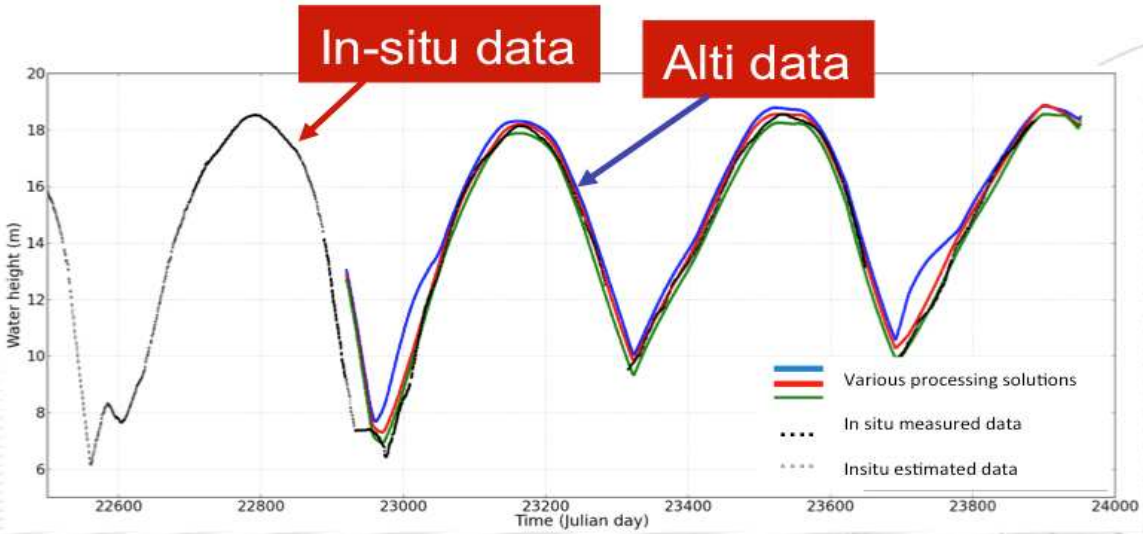
Multi-mission products wrt in-situ



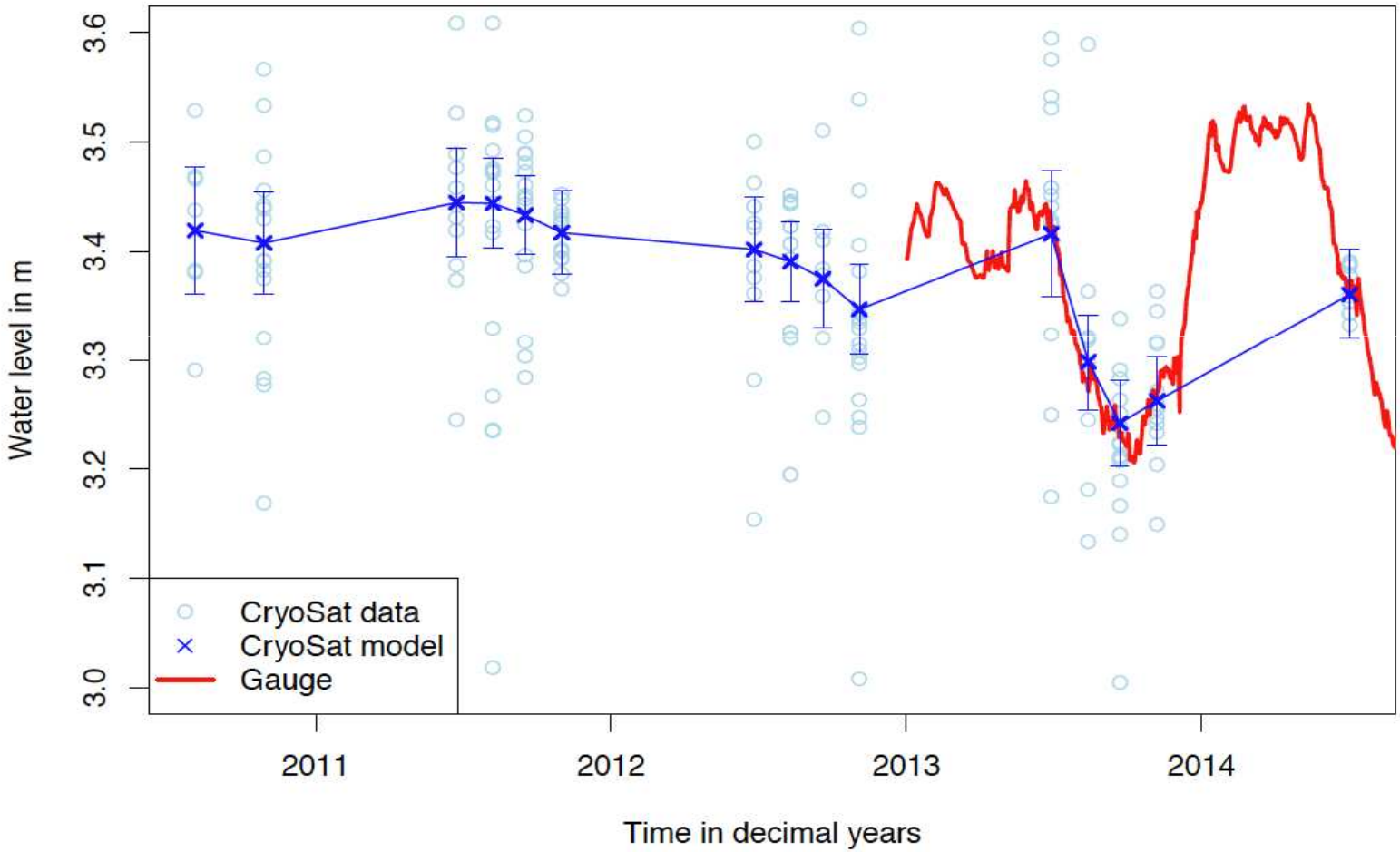
Distance to altimeter tracks :
- Jason-2: 100 km
- Saral: 50 km
- CryoSat-2: 3 km

Comparison with in-situ data must be done :

- ❑ Various processing configurations are analysed and compared
- ❑ Statistics are derived to quantify their relative performances



Time series of Arresø, Denmark (40 km^2)



Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen and Anders Nielsen karni@space.dtu.dk

- **Need to assimilate multi-mission products into models in order to:**
  - ❑ analyze their quality
  - ❑ improve the hydrological models and related forecasting

« Assimilation of virtual SWOT river water elevations in a regional hydrometeorological model »

V. Häfliger (,+) , E. Martin (*), A. Boone (*), F. Habets (#), C.H. David (@), P.A. Garambois (&), H. Roux (&), S. Ricci (**), L. Berthon (**), A. Thévenin (**), S. Biancamaria (++)*

* CNRM-GAME, UMR 3589, Météo-France, CNRS, Toulouse, France
\+ Centre National d'Études Spatiales, Toulouse, France
\# UMR 7619 METIS, CNRS, UPMC, Paris, France
@ Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
& Université de Toulouse, INPT, UPS, Institut de Mécanique des Fluides de Toulouse, Toulouse, France
** CERFACS-URA 1875, Toulouse, France
++ CNRS, LEGOS, UMR 5566-CNRS-CNES-IRD-Université Toulouse III, Toulouse, France

cnrs
dépasser les frontières

METEO FRANCE
Toujours un temps d'avance

Introduction

The main goal is :

- to study if the combination of SWOT data and hydrological models can help to **better represent the continental water cycle**, at the regional scale.

The two related objectives are :

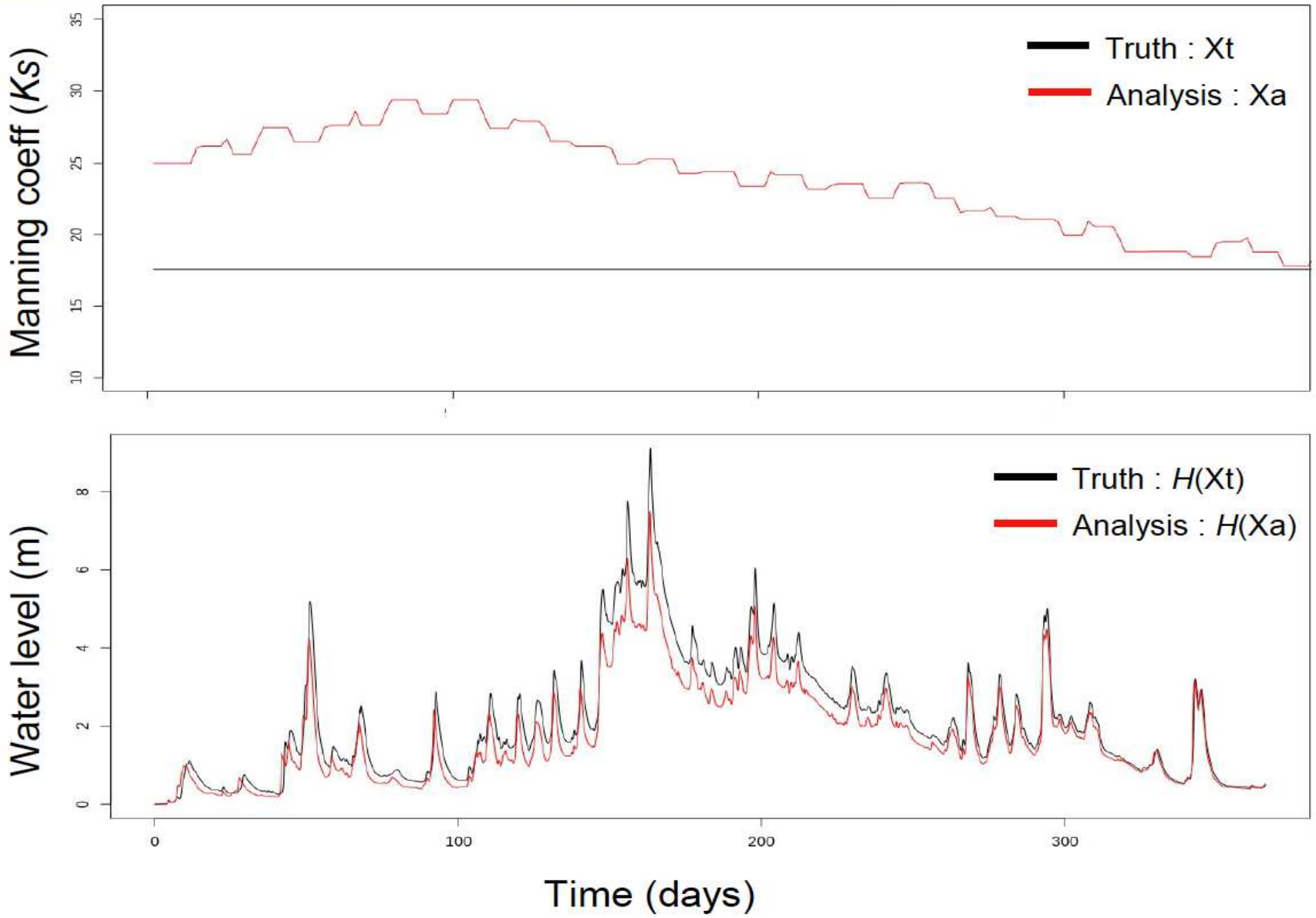
1. the introduction of **water level** simulations into a hydrometeorological regional model

2. to prepare hydrological regional models to **use SWOT data**, in order to **better estimate the water balance**.

⇒ To meet this objective, we propose to **assimilate virtual SWOT data** into a regional hydrometeorological model, in order to **improve the performance of the model**.

Assimilation : Impact on the river flows

Illustration at Bergerac (Dordogne river, France)



→ 3rd SPACE FOR HYDROLOGY WORKSHOP

Surface Water Storage and Runoff:
Modeling, In-Situ data and Remote Sensing

River discharge assessment at ungauged river sites by using water level time series derived by altimetry products: the case study of the Danube River

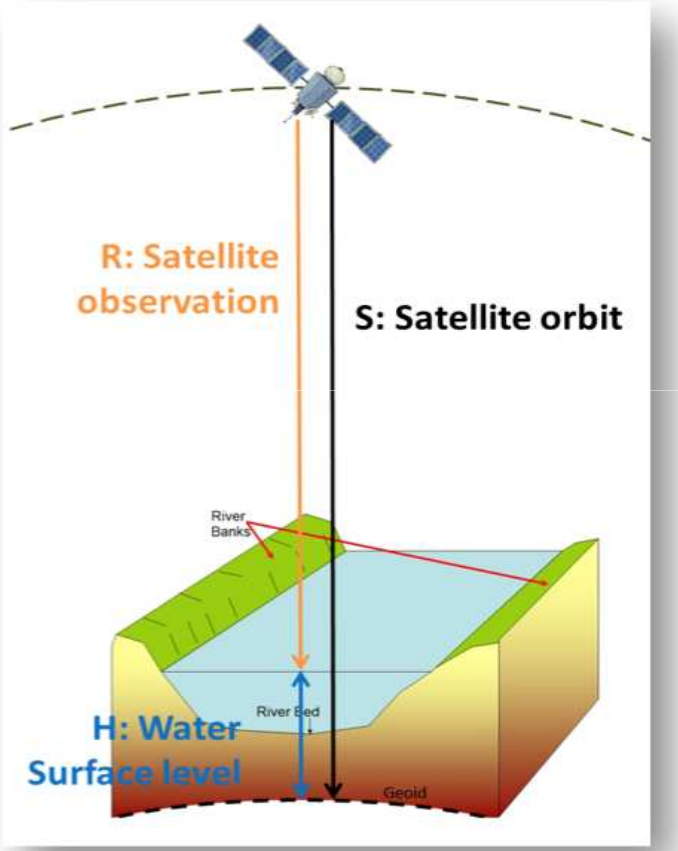
Angelica Tarpanelli, Luca Brocca, Silvia Barbetta, Tommaso Moramarco

Research Institute for Geo-Hydrological Protection, National Research Council, Perugia, Italy

15–17 September 2015 | ESA–ESRIN | Frascati (Rome), Italy

Introduction

RADAR ALTIMETRY FOR DISCHARGE ESTIMATION



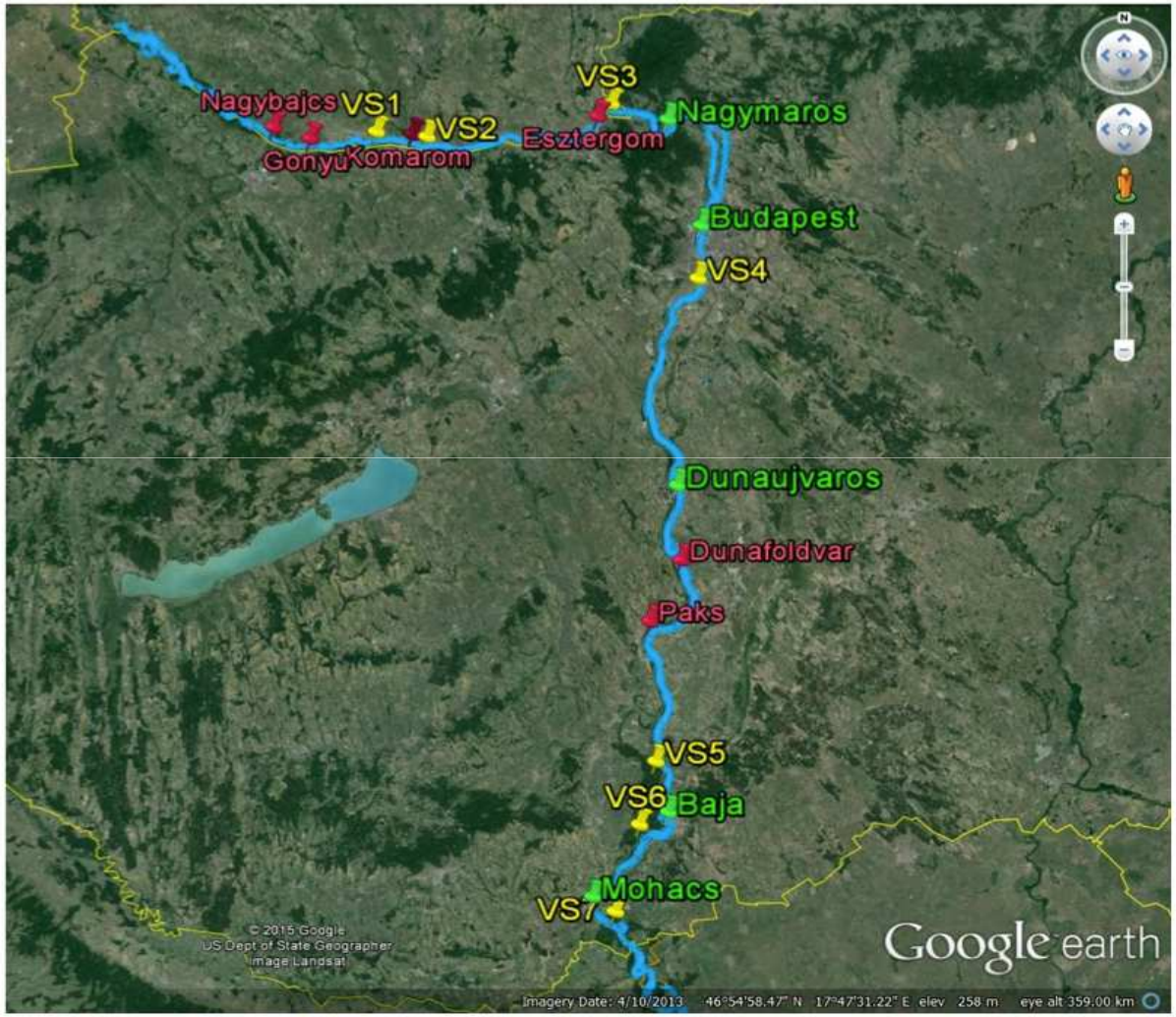
$$WS = S - R - \Sigma Corr$$

- **RATING CURVES** *(Leon et al., 2006 JoH; Papa et al. JGR; Tourian et al., 2013 WRR; Getirana et al., 2013 HESS)*
- **EMPIRICAL FORMULAS** *(Negrel et al., 2011 HESS; Michailovsky et al. HESS; Tarpanelli et al. 2015 JSTARS)*
- **HYDROLOGICAL MODEL** *(Milzow et al. 2009 JEM; Getirana et al., 2010 JoH; Paiva et al. 2013 WRR)*
- **HYDRAULIC MODEL** *(Birkinshaw et al., 2012 HyP; Domeneghetti et al., 2014; Tarpanelli et al., 2013 RS)*
- **ASSIMILATION TECHNIQUES** *(Biancamaria et al., 2011 RSE; Michailovsly et al., 2013 WRR)*
- **FUSION TECHNIQUES** *(Frappart et al., 2005 RSE; Creteaux et al., 2011 IWTC)*

Purpose

to present a methodology to estimate the discharge at ungauged river sites taking advantage of satellite altimetry water level measurements and very limited information at the ground

Satellite and *in-situ* data



***In-situ* data**

(from January 2002 to December 2008)

- Water level
- Water level
  - Discharge
  - Cross sections

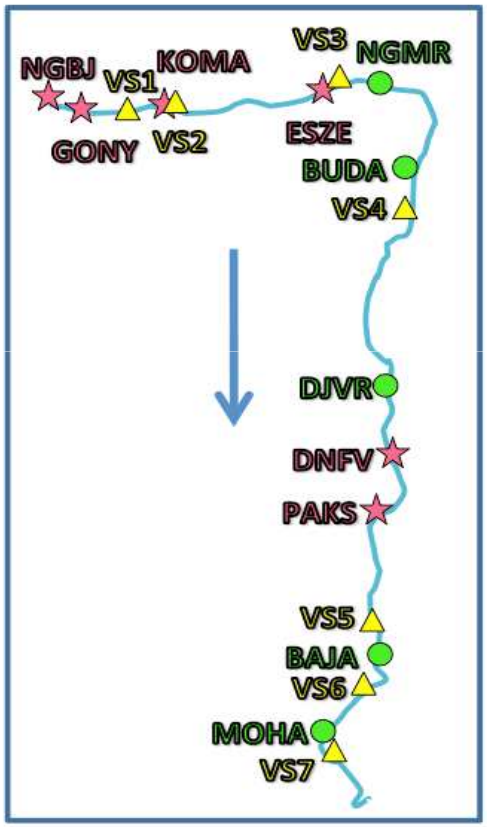
Satellite altimetry data

provided by ESA River and lake website (http://earth.esa.int/riverandlake)

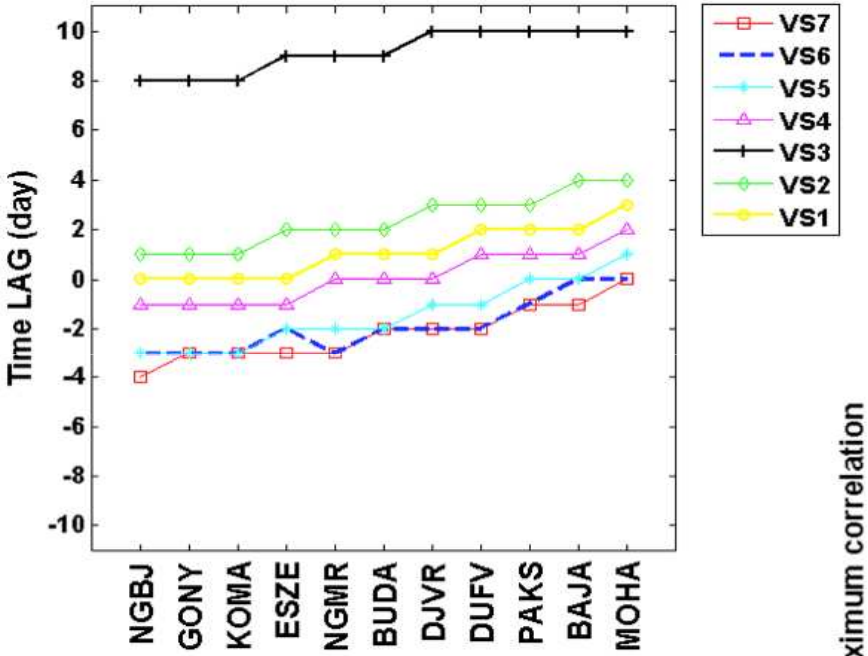
- Water level

Satellite and *in-situ* data

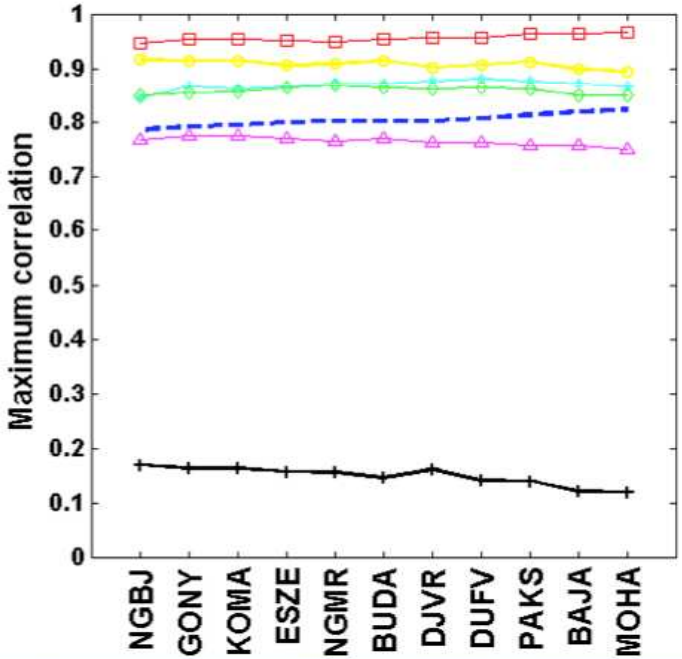
DANUBE RIVER



LAG

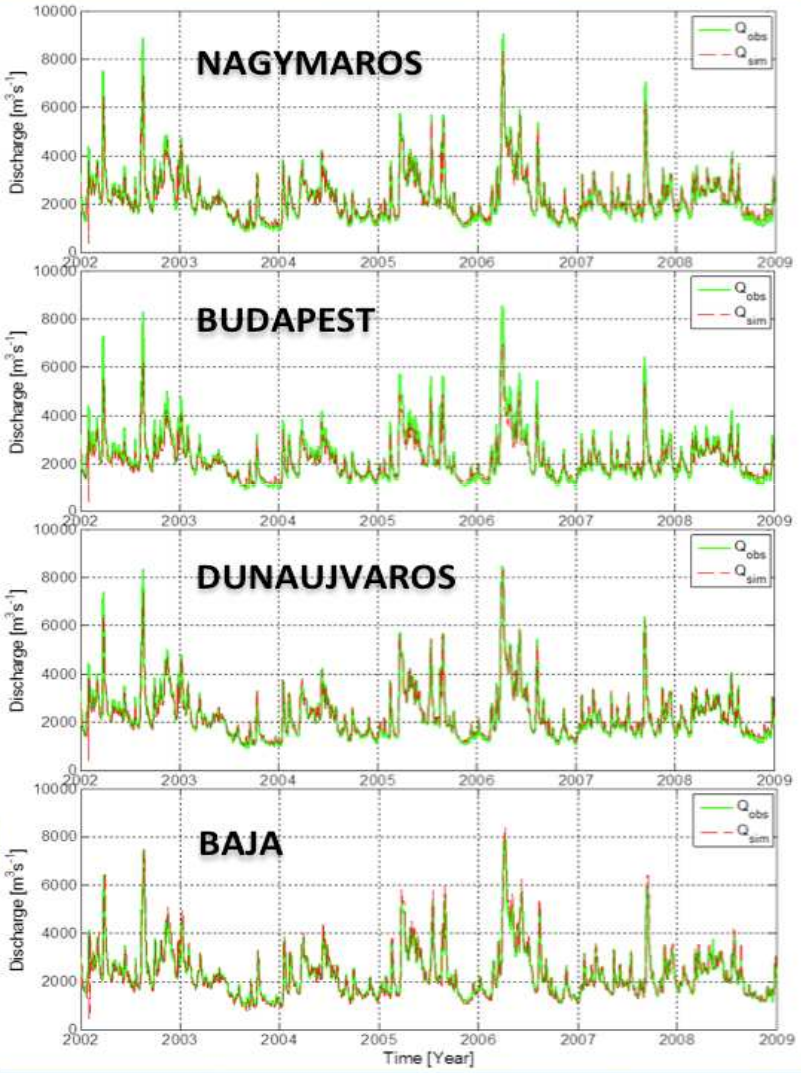


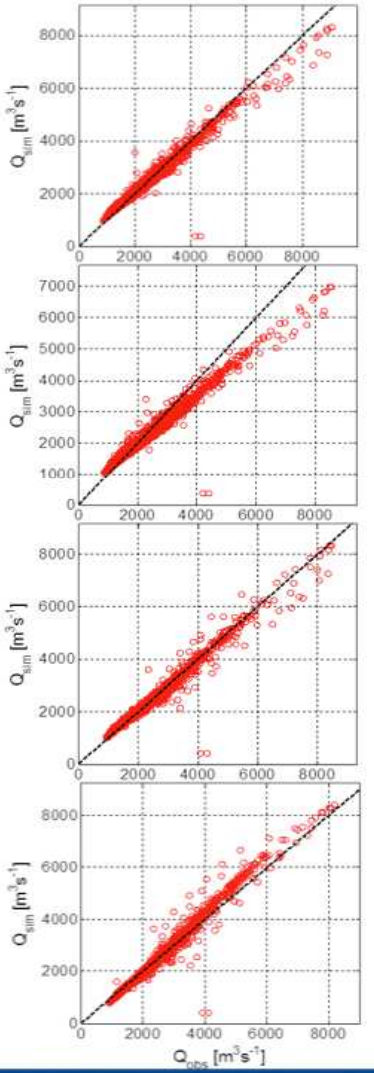
CORRELATION



Results: *in-situ* application

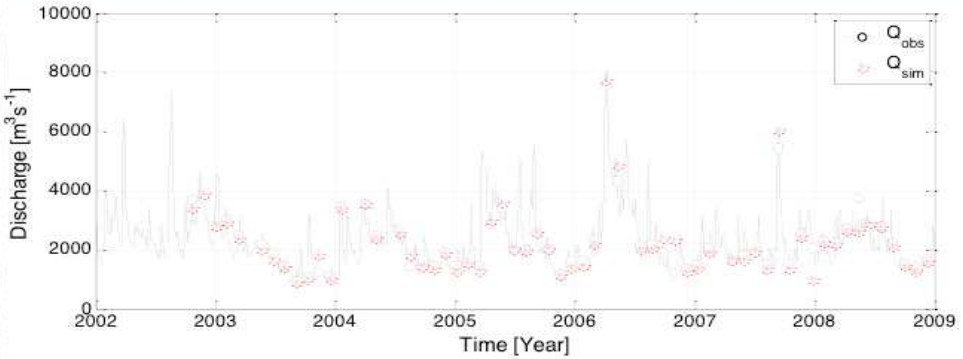
UPSTREAM	R^2	NS	fRMSE	R^2obs
NGMR	0.97	0.97	0.18	0.95
BUDA	0.97	0.92	0.29	0.96
DJVG	0.97	0.97	0.17	0.95
BAJA	0.98	0.96	0.20	0.97

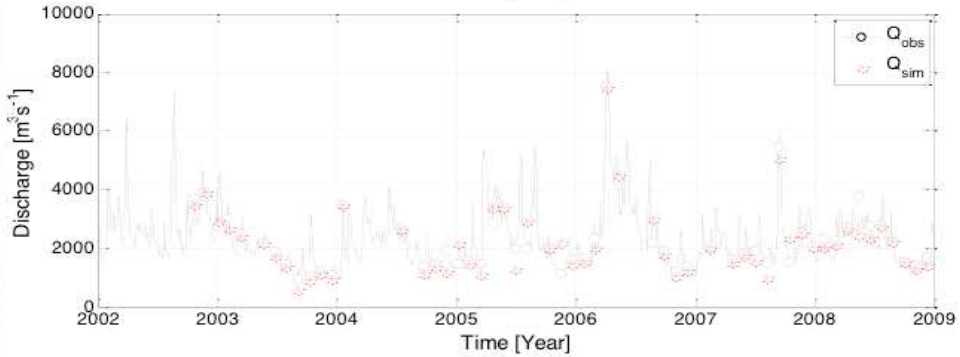


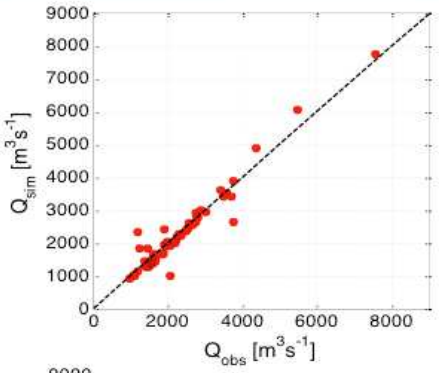


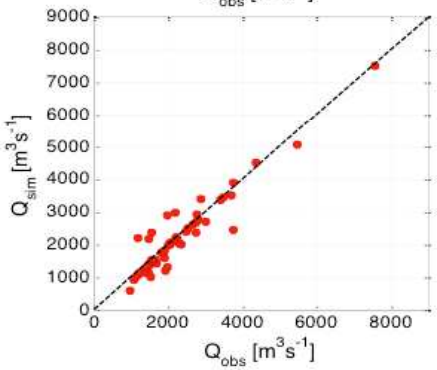
Results: satellite application

UPSTREAM	R^2	NS	fRMSE
VS1	0.95	0.91	0.30
VS2	0.91	0.87	0.36
VS4	0.77	0.72	0.52
VS5	0.93	0.92	0.28
VS6	0.89	0.88	0.34









Conclusions

- The comparison between the satellite and *in-situ* water level measurements has shown that ENVISAT time series are accurate to describe the water level observed along the river, except for one case in which there is disagreement between satellite and ground data (VS3).

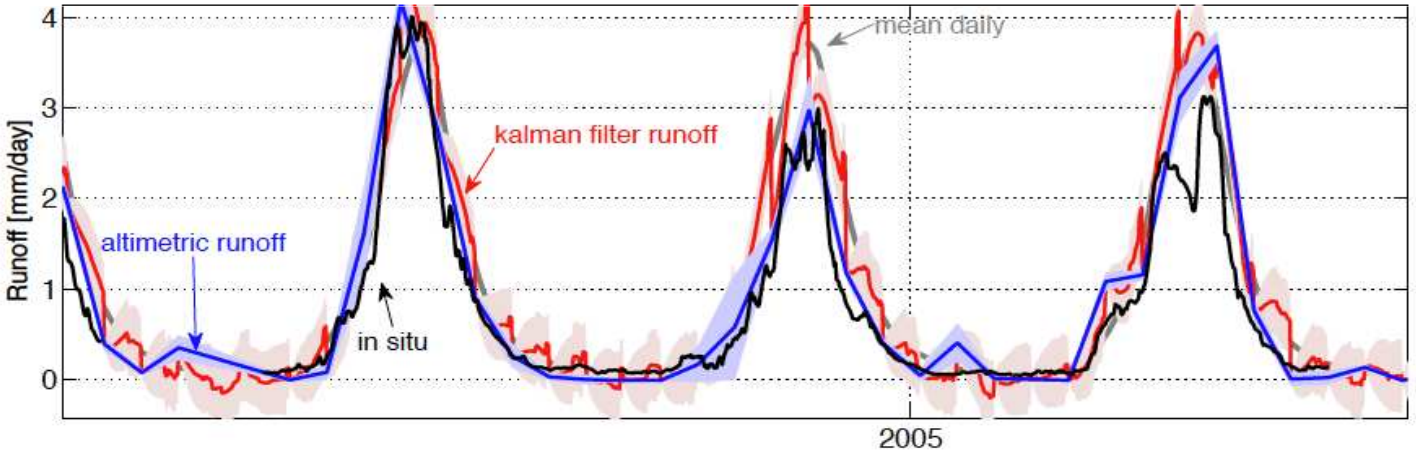
- Concerning the discharge assessment, the model performances are high. Specifically, the coefficients of determination varying from 0.97 to 0.98 by using *in-situ* water level and from 0.77 to 0.95 by using the water level derived by satellite altimetry.

- Based on the obtained results, the method could be appealing for river sites where altimetry data are available and geometric and hydraulic information at river section are absent or limited to low flow. Specifically, the method can be conveniently used in the ungauged sites where only a single station (downstream) is available with an accurate rating curve and a survey of the cross-section.

- Finally, it is worth noticing that an added value of the method is to infer information about the channel geometry in terms of river bottom level, which is of considerable interest for many satellite applications.

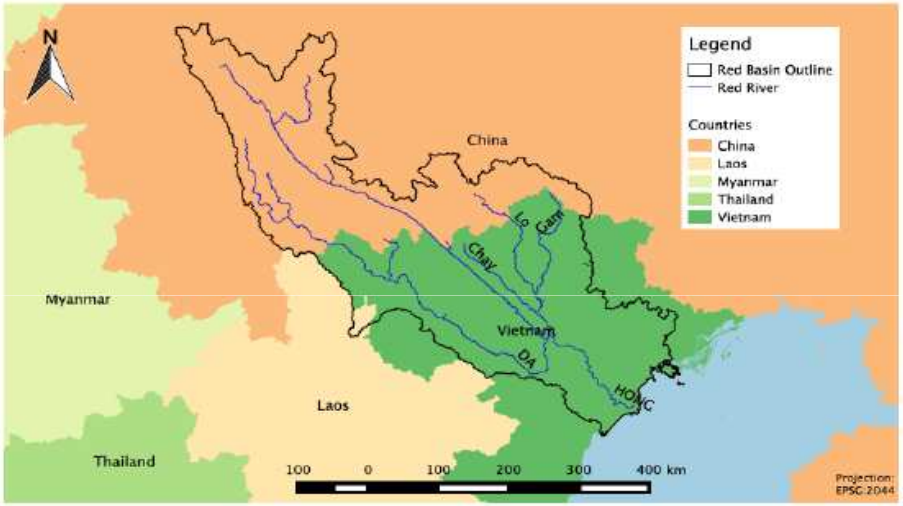
Results

- Training period: 1980–1990
- Validation period: 1990–2015
- In situ runoff data are excluded during validation period
- Observation equation during validation period contains only altimetric runoff

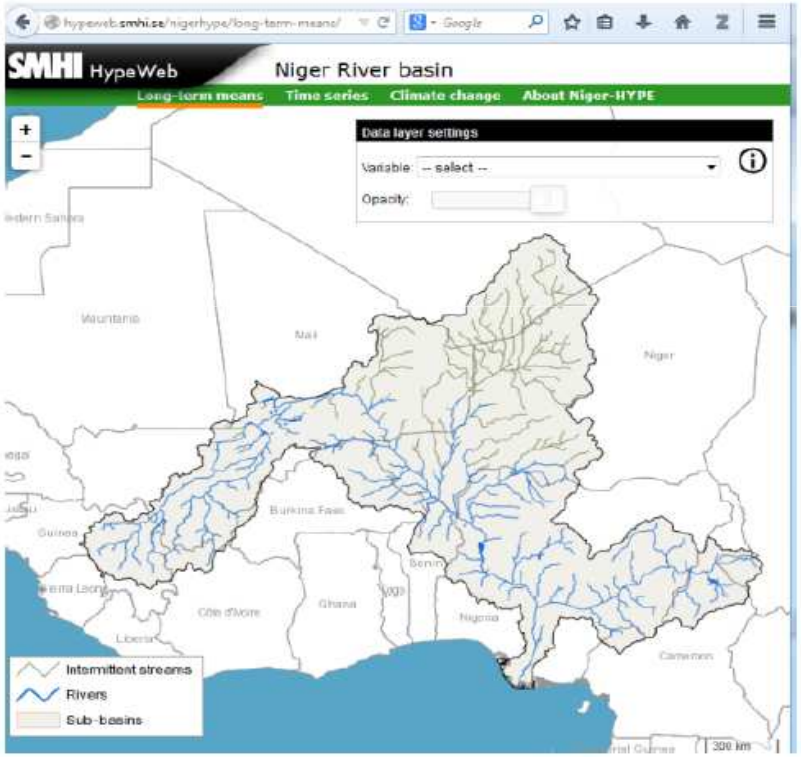


4. COMMUNITY PLATFORM: Pilot Project Users

RED RIVER (CHINA-VIETNAM)



NIGER RIVER (EAST-AFRICA)



USERS: AGHRYMET, DNH Mali, WASCAL Burkina Faso, ABN Niger, HUNRE Vietnam, WRU Vietnam…

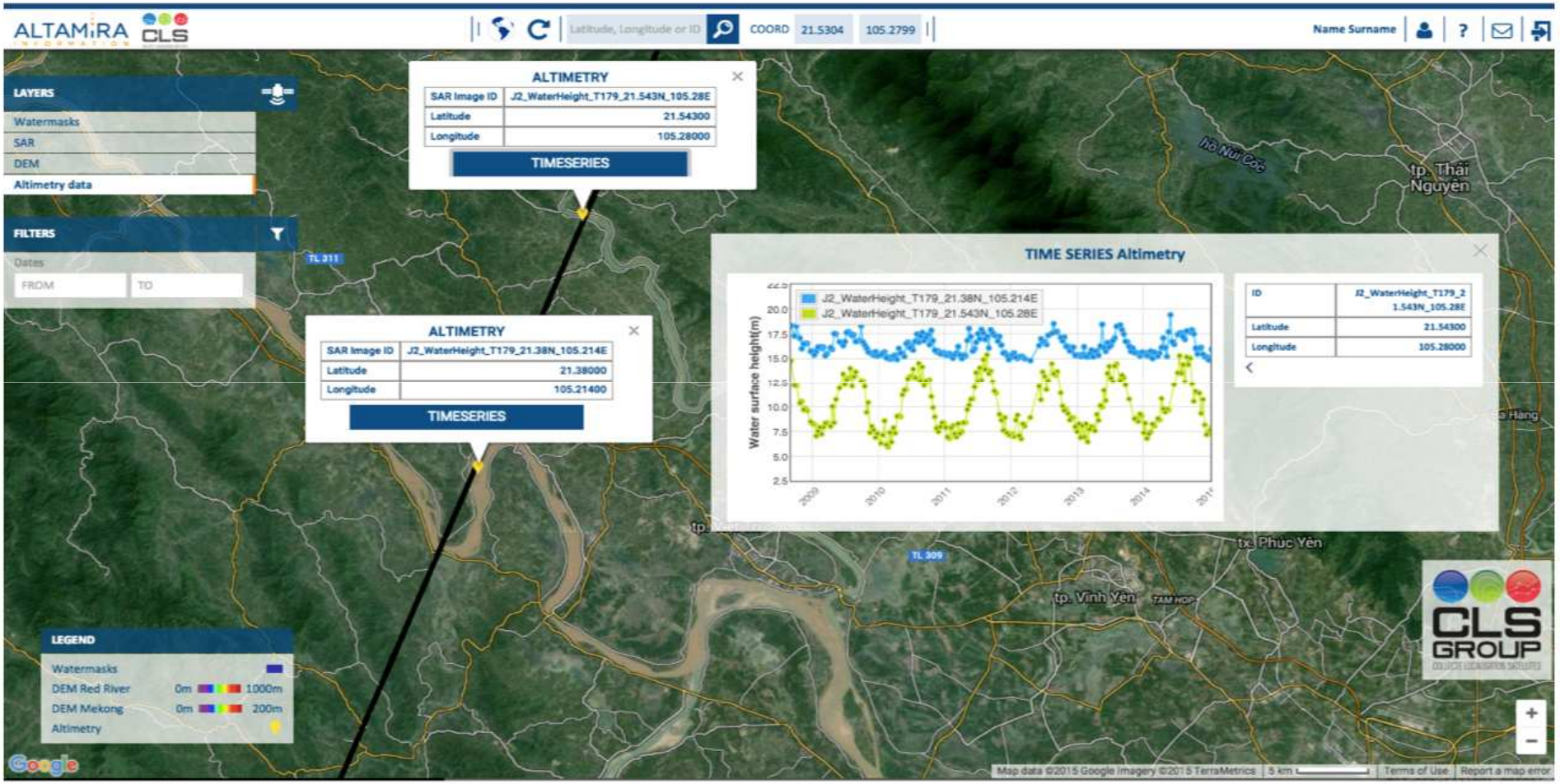
Operational Use of Satellites for Managing African Water Basins - A Case of Small Reservoirs in the Volta Basin

Frank Annor[1,2], A. Abbasi[2], Nick van de Giesen[2] , D. Eilander[2] & Gennadii Donchyts[2, 3]

(KNUST, Ghana[1] , TU Delft[2] & Deltares, Netherlands[3])

15-17 Sept.@ ESA, Hydrospace 2015, Frascati, Italy

Web application for the visualization of hydrological products



Water levels time series from Altimetry virtual stations.

Recommendations

- The need **to validate data products** and models (water level retrieved by altimetry, bathymetry derived from optical imagery and flood inundation areas by hydrodynamic models) has emerged from all the presentations of the session.
- The major concerns in the development of methods for calculations and predictions with respect to water resources in the long or short term is **a short length of field observations for river flow or lack thereof**.

Recommendations

- There is an **increasing need of in situ observations** (hydro-monitoring network, field surveys, etc.) to be used for testing and improving the methodology. Help **on access in-situ data**!
- Agencies should **support the in situ network** they need for calibration… especially in Africa.
- It is recommended that **“hot points”** are commonly established in selected areas on Earth where **in situ** data are available for thorough comparison and **validation of satellite measurements**.

Recommendations

- The low temporal resolution that characterizes the satellite missions often is not adequate for catching the flow regime in a river. Quite promising results were presented by using **multi-mission series** for improving the time scale. To be encouraged!
- The necessity of focusing future research on the estimation of the **bias among the different satellite** missions was emphasized

Recommendations

- The difficulties in the quantification of errors from spaceborne sensors is an important issue above all for ungauged basins. The data user and supplier communities should work hand in hand **to establish standards for error estimations**.

Recommendations

- Provide **water body mask** every 12 days (S1 repeat orbit)
- River **bathymetry** is by far a challenging task for spaceborne sensors. However, this is a crucial parameter for hydrogeological risk management and discharge monitoring. Further efforts should take into account addressing its determination.

Recommendations

- Continue to bring together the **in situ** data providers, products providers from **space** agencies and **water managers**

- **Next Hydrospace planned in Spring 2017**

Thank you for your attention